Journal of Human Performance in Extreme Environments

Volume 7 | Issue 2 Article 7

Published online: 10-1-2003

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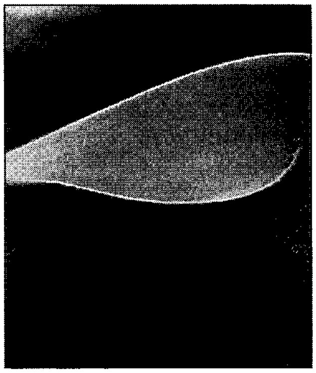

Evaluating Human Performance and Advanced Technology Design in Extreme Environments

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Evaluating human performance in extreme environments offers unique challenges to human factors practitioners, researchers, and designers. Existing methodologies do not facilitate making cross-modal comparisons of cognitive-attentional demand levels. The present paper describes a multi-sensory protocol device for the evaluation of workload when assessing human performance and the differential demands placed upon sensory modalities.

The tactile component is presented by means of a custom-built wearable vibrotactile display consisting of three vibrotactile actuators attached to an elastic Velcro belt.

Operating in extreme environments offers unique challenges to designers, many of which seek to mitigate environmental performance handicaps through advanced technology use. However, designers must not only take into consideration physical performance limitations imposed by extreme environment (e.g., making psychomotor responses while wearing gloves or while under g-stress), they must also consider any potential cognitive-perceptual impairments arising from operating in extreme environments and while under stress (e.g., Baddeley, 1972; Graybiel & Knepton, 1976; Hancock & Warm, 1989; Manzey, Lorenz, & Poljakov, 1998). However, operators who are cognitively impaired due to extreme environment exposure are, by definition, largely incapable of making accurate subjective reports regarding their state. Therefore, performance-based methodologies of workload evaluation are likely of greatest utility. Additionally, existing methodologies are incapable of differentiating between the demands placed upon sensory information channels across tasks (Meshkati, Hancock, Rahimi, & Dawes, 1995), thereby limiting their utility.

The Multi-Sensory Workload Assessment Protocol (M-SWAP) was developed to meet these needs. It is comprised of a multi-sensory complex counting task administered via a secondary task paradigm and is based upon previous work by Jerison (1955) and Kennedy (1971). The visual component of M-SWAP is administered via a 3.5 in LCD that accepts a video signal from a laptop computer. The auditory component is presented by way of headphones. The tactile component is presented by means of a custom-built wearable vibrotactile display consisting of three vibrotactile actuators attached to an elastic Velcro belt. The display is configured to present vibration at three equidistant loci on the abdomen, the spacing of which is sufficient for a high degree of discrimination (Cholewiak, Brill, & Schwab, in press). The actuators load against the skin with approximately 50 g of force. The tactile signals consist of 250 Hz sinusoidal vibratory bursts presented at approximately 24 dB above threshold.

Operators are presented with a random series of visual, auditory, or vibrotactile signals from which they count pre-specified target signals and make a psychomotor response (hitting a button). Data are analyzed in terms of traditional signal detection metrics (e.g., hits, misses, false alarms). The number of counting errors serves as a measure of workload, wherein low workload tasks should be associated with few counting errors and high workload tasks should be associated with greater frequencies of counting errors. Pilot studies suggest that M-SWAP is highly reliable

http://dx.doi.org/10.7771/2327-2937.1032

across administrations (ρ = .961 - 1.0; $p < .03$), and current research efforts seek to further establish the reliability and validity of the protocol.

The versatility of M-SWAP makes it an appropriate tool for performance evaluation in extreme environments and a system design aid for extreme environment technologies with implications for both theoretical and applied research.

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